

Conflicts in the roof: system performance of PVT-HP systems combined with solar thermal areas for different climatic conditions in Germany

Herena TORIO^{1,2}, Adrian JIMENEZ¹, Jifin DEVASSYKUTTY¹, Patrik SCHÖNFELDT², Peter KLEMENT²

¹, Energy Technology, Institute of Physics, University of Oldenburg; ², DLR (Deutsches Zentrum für Luft und Raumfahrt) Institute of Networked Energy Systems

Introduction

- PVT may be an alternative to boreholes or air heat pumps (where these options due to noise or space constraints may not be an option).
- But the roof space is limited, specially in multi-family dwellings (MFH). So: can the performance of PVT be increased with solar thermal or photovoltaic systems?
- Possible advantages of **solar thermal source**
 - Increase the source temperature (as compared to air)
 - Better system efficiency
 - Different benefits for different weather conditions
- Possible advantages of **photovoltaic use**
 - Increase the self-sufficiency for electricity supply
 - Lower costs

Method

- Techno-economic optimization using MTRESS [1]
 - Thermal collector as simplified linear model:
 - Based on input data from data sheets
 - 2-step calibration using WPuQ data [2]
- I. Model Calibration (ScenoCalc)**

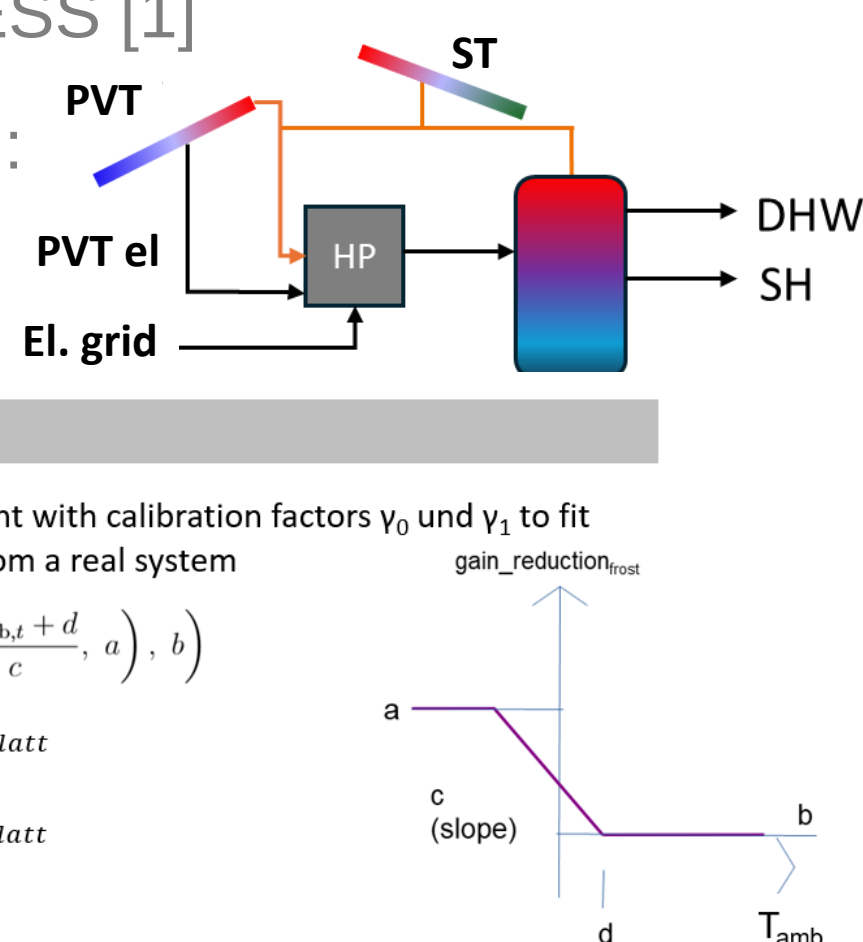
 - adjusting data sheet coefficients with calibration factors f_0 and f_1 to standard performance models
 - Optimization for minimization of the deviation of daily heat balances
$$\eta_0 = f_0 \cdot \eta_{0, \text{Datenblatt}}$$

$$\alpha_1 = f_1 \cdot \alpha_{1, \text{Datenblatt}}$$

II. Frost Calibration

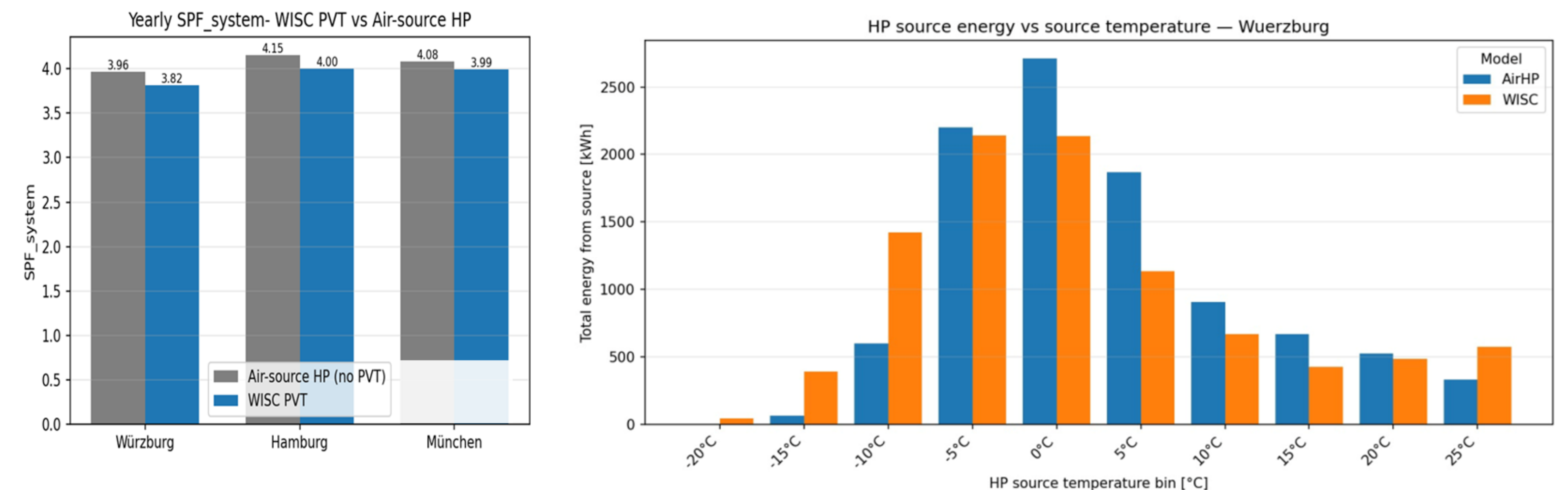
 - Further adjustment with calibration factors γ_0 and γ_1 to fit measurements from a real system
$$\gamma_1 = 1 + \min \left(\max \left(\frac{T_{\text{amb}} + d}{c}, a \right), b \right)$$

$$\eta_0 = \gamma_0 f_0 \cdot \eta_{0, \text{Datenblatt}}$$

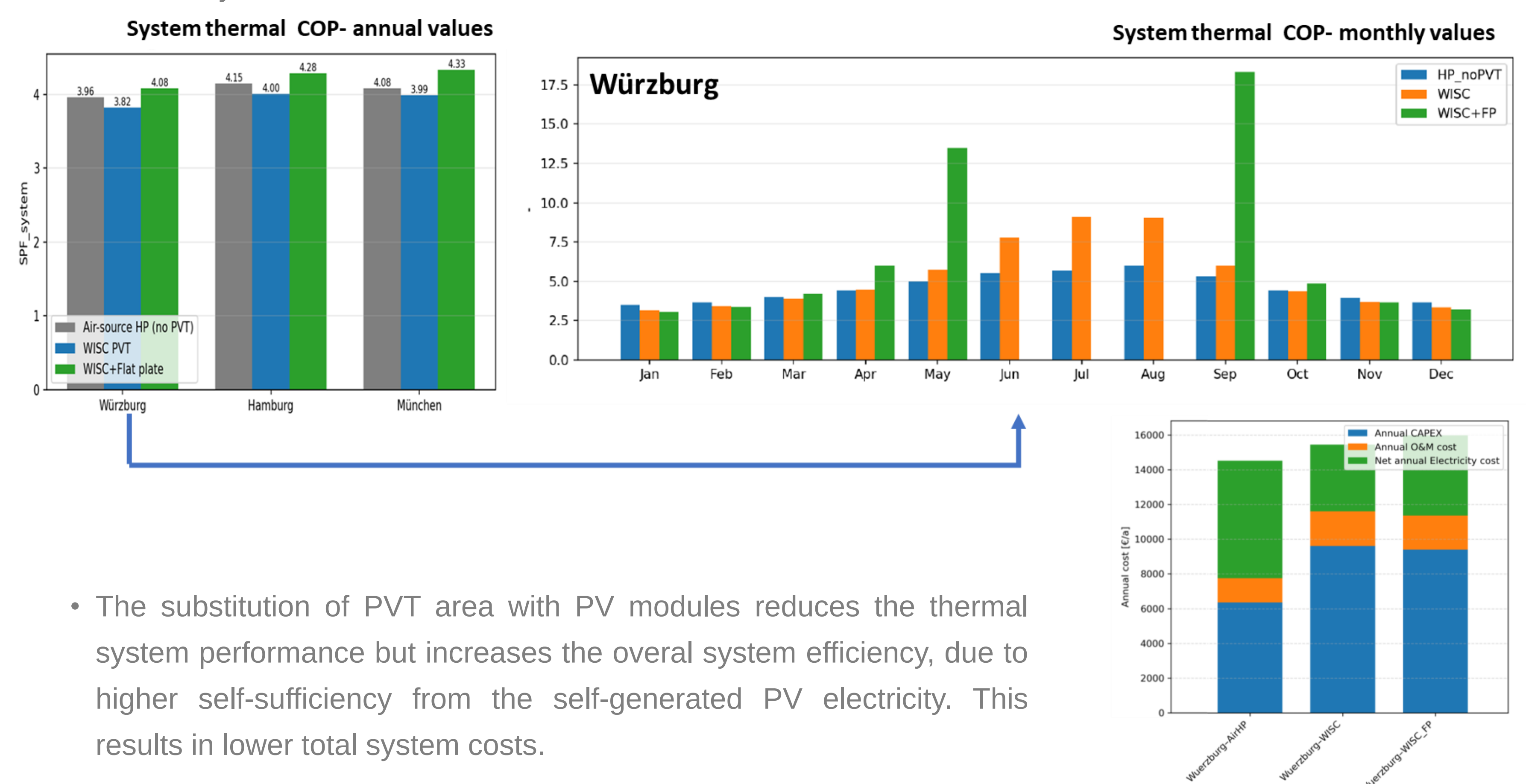
$$\alpha_1 = \gamma_1 f_1 \cdot \alpha_{1, \text{Datenblatt}}$$
- 
- Linear model for the heat pump (discrete temperature levels to choose between for the operation)
 - Weather data for Munich, Hamburg, Würzburg from PVGIS [4]
 - Pre-calculated time-series for $COP_{HP}(T, t)$ and $\eta_{ST}(T, t)$
 - Energy demands for SH and DHW in MFH generated using demandlib [3]
 - Electricity prices assumed as 0.35€/kWh, no feed-in tariff
 - Costs for components partly based on own survey [5]

Results

- The use of PVT (passive air contact) tends to reduce the source temperatures as compared to ambient air (active ventilation) as source. This leads to a reduction in the system performance in winter.



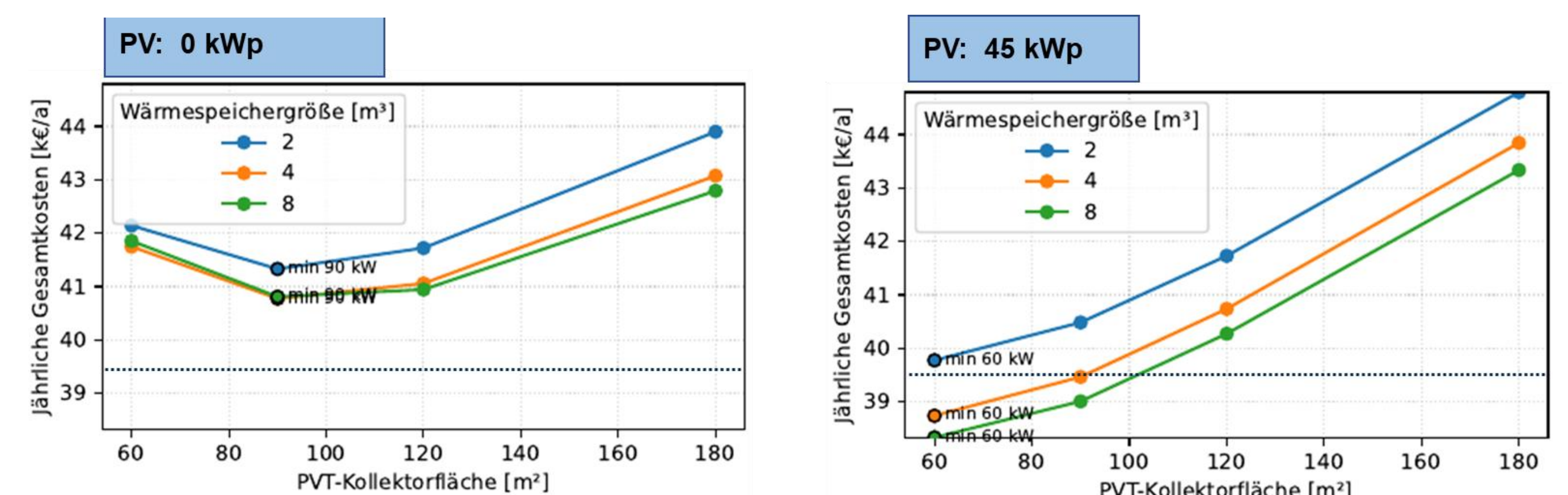
- The substitution of 1/3 of the PVT area with solar thermal collectors increases the thermal performance of the system, mainly due to increased source temperatures for the heat pump and direct heat supply in summer, autumn and spring. However, the total annual system costs increase due to lower self-sufficiency.



- The substitution of PVT area with PV modules reduces the thermal system performance but increases the overall system efficiency, due to higher self-sufficiency from the self-generated PV electricity. This results in lower total system costs.

Discussion

- The simplified collector model is suitable for assessing the overall energy system performance, including seasonal effects (provided sufficient quasi equilibrium operation is possible) and both, energy supply as source to the heat pump and direct supply to the system demands.
- The temperature levels supplied in winter by the PVT for the weather conditions investigated are lower than ambient air. The performance of these components may be significantly higher for cold but sunny winter places.
- Self-sufficiency of electrical supply is one of the major parameters for reducing total system costs.
- The installations costs assumed for PVT are around double the costs for photovoltaic systems. If these costs are reduced (e.g. due to scale effects), the benefits of exclusive PV areas may be reduced significantly.



Conclusions

- Substituting a part of the PVT area with solar thermal collectors reduces the overall system performance: it increases the thermal efficiency but reduces the self-sufficiency in the electricity supply of the whole system, leading to higher total annual system costs.
- For the integrated system performance, i.e. including thermal and economic benefits, PVT areas can be complemented with PV. The reduction in the PVT areas to be used as source lead to a reduction in the thermal performance that is compensated by higher self-sufficiency in the electricity supply, leading to lower total system costs.
- The trends above may be extrapolated for other electricity prices (including feed-in tariffs) as long as the electricity costs are significantly above the levelized costs of energy from photovoltaic systems.

References

- [1] MTRESS: <https://github.com/mtress/mtress>
- [2] WPuQ dataset, doi: 10.5281/zenodo.5642902
- [3] Demandlib (now oemof.demand): <https://github.com/oemof/oemof-demand>
- [4] PVGIS: <https://photovoltaic-geographic-information-system.ec.europa.eu/en>
- [5] <https://garten.coolewaerme.uol.de/komponentenkosten/>